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THE RED BLOOD CORPUSCLE IN LEGAL MEDICINE.

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Much has been written on this subject, and Clark Bell, Esq., in an able symposium, has shown that the consensus of scientific opinion may be summarised in the following declaration, viz., that "by careful and competent observers, with instruments of high power, a reliable discrimination can be made between human blood and the blood of other mammals, when the size of the red corpuscle is much smaller than those of man, notably in the case of the ox, the horse, the goat, the sheep, the pig and most other mammals."

In contravention of this opinion, Professor Marshall D. Ewell, M. D., in his address delivered at Rochester, N. Y., in August, 1892,* advances the opinion that "the very utmost the present state of science enables us to state is that the blood in question is or is not that of a mammal, a bird, fish or reptile. To say more than this is, in my judgment, without warrant to imperil human life, and, in the words of the late Dr. Woodward, to make scientific experts more dangerous to society than the very criminals they are called upon to convict."

As this startling proposition has never been answered in the TRANSACTIONS of the American Microscopical Society, I offer the following discussion of the subject, which I had the honor to read before the Medico-Legal Society in December, 1894. Professor Ewell's arguments, which I controvert, will be found in the TRANSACTIONS of this society and in the *Medico-Legal Journal*, Vol. X., No. 2, September, 1892.

Professor Ewell ruled a series of eleven lines on glass, giving ten spaces of approximately 0.004 inch, and another set with five spaces about 0.008 inch, and gave these plates to several microscopists to report from careful measurements the values of the ruled spaces. According to Professor Ewell, in the results of the measurements made by the six microscopists, there were differences in the results of their measurements greater than $\frac{1}{9000}$ of an inch, which Professor Ewell says is greater than the greatest difference between the different measurements of the blood corpuscles of man and some common domestic animals, *i. e.*, dogs. Although these measurements were made with low powers, 1 in., $\frac{2}{3}$ in., $\frac{1}{2}$ in., $\frac{4}{10}$ in., $\frac{1}{4}$ in., and $\frac{1}{5}$ in. objectives, giving magnifying powers approximately of 100 to 500 diameters. Professor Ewell appears to think such powers might give as accurate measurements as higher powers. He says:

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* TRANSACTIONS American Microscopical Society, Vol. XIV.

> To the objection that a low power was used in every instance, it may be answered that where the power is high enough to make the object clearly visible and of an appreciable size, as was the case in these measurements, and where a series of measurements are made, the result is practically the same as if a higher power were used.

The consequences of this startling proposition are too great to allow it to be passed over without careful criticism.

Gulliver's measurements of blood corpuscles were made with a magnifying power of 600 diameters. Woodward, Richardson, Treadwell, Wormley, Piper, Formad and most microscopists who figure in Medico-Legal cases at the present day, have used powers ranging from 1,000 to 2,500 or 3,000 diameters. Professor Ewell, himself, favors 1,000 diameters for use in measuring blood corpuscles, and yet he puts forth the discrepancies between measurements of different observers with powers of 100 to 250 diameters to discredit the distinctions observed with powers of 1,000 diameters, or even 3,000 diameters between the blood corpuscles of man and the domestic animals.

As a further answer to Professor Ewell we may cite observations recorded by Professor Wormley, in Micro-Chemistry of Poisons, page 728, wherein a series of ten spaces ruled on glass, measured by three observers with different instruments, the results did not differ more than $\frac{1}{200000}$ of an inch. Also two independent series of measurements with high powers, of twenty designated blood corpuscles were absolutely identical for sixteen corpuscles, and for the other four the greatest difference was only $\frac{1}{200000}$ of an inch. Still further, Professor Wormley reports the measurement of seven human blood corpuscles with powers varying from 1,150 to 3,500 diameters by different micrometers, and by drawing with the camera lucida. The range of averages of the different measurements was $\frac{1}{3224}$ of an inch, to $\frac{1}{3275}$ of an inch, as measured by the camera lucida. The mean of the averages being $\frac{1}{3236}$ of an inch. The same seven corpuscles measured by Dr. Richardson, using a cobweb micrometer, gave a final average of $\frac{1}{3266}$ of an inch, differing from the former average by something less than $\frac{1}{350000}$ of an inch.

To further show the uniformity of results obtained by different observers, I would mention that on a slide of human blood irregularly spread and dried so that the corpuscles on one-half of the slide appeared larger than on the other part, Dr. T. measured, with high powers, seventy-five corpuscles on the side showing the larger, and seventy-five on the side showing the smaller corpuscles. The average of the 150 corpuscles thus measured was $\frac{1}{3667}$ of an inch. The writer using a power of 1,400 diameters and a cobweb micrometer measured fifty corpuscles on one part of the same slide and fifty on the opposite part of the slide, and found the average of the 100 corpuscles to be $\frac{1}{3665}$ of an inch, differing by only $\frac{1}{6719777}$ of an inch from the results obtained by Dr. T. on the same slide.

With the above demonstrations of corresponding results of measurements made by the microscope in the hands of independent observers, using powers of 1,000 diameters and upward, I think I may dismiss the objections of Professor Ewell, based on slight differences obtained by different observers with powers ranging from 100 to 400 diameters, whether due to defects of instruments or to the personal equation of the observers.

1. The woolly appearance and uncertain limit of the blood corpuscle is claimed to interfere with accurate measurements.

In answer to this objection, I present photographs of the human blood corpuscle magnified 630, 840, 2,560 and 10,850 diameters respectively; which, I think, show about as sharp edges as any objects can show with such enlargement.

Again, the fact that different observers working with different instruments can and have measured a series of corpuscles with results differing less than $\frac{1}{900000}$ of an inch, shows a mutual agreement in regard to the exact limit of the border.

The chief cause of the indistinct outline of the edge of the corpuscle may be accounted for by the excessive thinness of its edge, which is very translucent.

Another fact in regard to the limit of the edge of the corpuscle to be measured, arises from the fact that the corpuscle of mammalian blood is a bi-concave disc, with a thick border, thin at the center and falling off to a rounded edge, which, acting like a section of a convex lens, produces the appearance of a dark ring surrounding the corpuscle. Some observers measure the whole of this dark ring, others measure one-half the ring, and a few perhaps reject the dark border as no part of the corpuscle.

The late Dr. Woodward of the U. S. army, measured from the center of the dark border of the corpuscle on one side to the center of the dark border on the other side because (as he said in his testimony at the Hayden trial in New Haven in 1879) he could bring the spider lines of the micrometer to the center of the border on each side with more certainty, than he could bring them to the edges of the corpuscle. Others have pursued substantially the same course, so that in the reports of measurements of blood corpuscles published in the journals, and in works on legal medicine, we know not how much of the corpuscle was really measured by the different observers. Now, as the dark border of the corpuscle has a breadth of about one quarter of a mikron, or $\frac{1}{100000}$ of an inch, this mode of measurement would reduce the average diameter of the human blood corpuscles from $\frac{1}{3200}$ inch, to $\frac{1}{3806}$ of an inch, or if the dark border was rejected altogether, the average diameter would be reduced to $\frac{1}{3412}$ of an inch, which is exactly the diameter given by Hans Schmid in 1878. These facts show that in quoting the standard measurements made by experts, we ought to be informed how much of the corpuscle was measured, if we would compare the work of one expert with the measurements made by another.

I have satisfied myself that the whole of the dark border on both sides of the corpuscle should be measured. I have ground glass discs in the form of the human blood corpuscle, and found that the border of the dics presented a dark ring like that seen when the blood corpuscle is seen in the microscope. I have also carefully measured the corpuscle seen by transmitted light showing the dark border, and have also measured the same corpuscle seen by reflected light, in which the border did not appear dark but of a color like the rest of the corpuscle, and I have found the measurement in the two cases the same.

Among the most valuable recent contributions to the study of blood corpuscles, is the article of Prof. Marshall D. Ewell in the *Medico-Legal Journal*, Vol. X., No. 2, September, 1892, which I have referred to above.

After noting differences in the results of measurements of spaces ruled on glass, which we have noted above, he shows by measurements of 100 corpuscles of his own blood, taken on six different days, that there were slight differences on the different days, varying from 9.05 mikrons to 8.23 mikrons, the general average being 8.03 mikrons, the greatest average differences on different days being about $\frac{1}{90000}$ of an inch ; showing that for the same individual while in health, the average of 100 or more corpuscles remains substantially constant.

The following table of measurements of blood corpuscles of man and domestic animals, which I published in *Wood's Handbook of Medical Sciences*, is better adapted for the purposes of this discussion than any other with which I am acquainted. This table was reduced by the writer from measurements made by the late J. B. Treadwell, M. D., of

Boston, with a $\frac{1}{25}$ inch objective, made by R. B. Tolles, and a Jackson eye-piece micrometer made by Tolles, ruled by Professor Rogers, and a stage micrometer, ruled, tested and rated by Professor Rogers:

SOURCE OF BLOOD. Measurement in *Mikrons.* By J. B. TREADWELL, M. D.*	No. of Discs.	Mean Diam.	Max. Min.	Av. by 10's.	Av by 20's.	Av. by 50's.	Av. by 100's.	Av. by 200's.
Five men, ages 23 to 49 years.	1000	7.941	5.773 9 394	7.697 8.152	7.782 8.110	7.845 8 061	7.884 8.046	7.903 7.983
Five women, ages 18 to 55 years	1000	7.927	6.350 9.287	7.825 8.152	7.787 8.026	7.873 7.993	7 901 7.963	7.913 7.950
Three infants at birth, 1 male, 2 females	600	7.950	4 233 10.160	7.667 8.298	7 716 8.100	7.833 8.031	7.918 7.983	7.938 7.970
Boy, 8 years old	200	7.983	6.929 9.160	7.747 8 282	7.828 8.191	7.891 8.079	7.965 8.000	7.983
Man, 70 years old	200	7.916	7.005 9.236	7.658 8.121	7.662 8.105	7.768 8.028	7.852 7.980	7.916
Fifteen persons, as above	3000	7.938	4 233 10.160	7.658 8.298	7.662 8.191	7.768 8.079	7.852 8.046	7.903 7.983
Blood stains (human) restored	1000	7.910	5 570 9 687	7.700 8.189	7.723 8.010			
Woman, 19 years old, anemia	100	7.346	3.464 9.237	6.674 7.605	7.012 7.628	7.177 7.515	7.346	
Child, 6 weeks old, starved to death	100	7.573	4.465 8.636	7.328 7.712	7 493 7.639	7.572 7.574	7.573	
Twenty-five dogs, each 100 corpuscles	2500	6.918	4.618 8.931	6.138 7.352	6.445 7.305	6.523 7.258	6.673 7.198	
Pigs, 2 of 3 months, 1 of 2 weeks	600	6.101	3.849 8.391	5.418 6.520	5.757 6 466	5.880 6.246	6.028 6.169	6.069 6.144
Ox, 3 males, 2 females; 1 of 1 day, 1 of 3 months	1000	5.436	3.916 6.774	5.150 5.703	5.296 5.622	5.345 5.543	5.347 5.482	5.406 5.461
Horse, 10 years old	200	5.503	4.618 6.774	5.203 5.818	5.257 5.633	5 473 5.553	5.493 5.513	
Ass, 1 male, 1 female	400	6.293	5.003 7.697	6.018 6.566	6.138 6.539	6.201 6.377	6.219 6.376	6.259 6.326
Mule, 6 years old	200	5.421	3.464 6.312	5.280 5.680	5.327 5.545	5.377 5.472	5.419 5.424	
Two cats, 1 adult, 1 kitten 3 weeks old	400	5.463	2.617 6.774	4.311 5.780	4.361 5.676	5.268 5.573	5.419 5.522	5.431 5.495
Male cat, stupefied 5 hours by alcohol	100	5.489	4.772 7.235	5.327 5.680	5.426 5 846	5.479 5.498	5.489	
Guinea-pig, male, 3 months	200	7.476	5.849 8.390	7.231 8.698	7.309 7.659	7.249 7.634	7.393 7.559	
Two rabbits, 1 white, 1 mixed	400	6.365	4.618 8.082	6 196 6.596	6.227 6.845	6.294 6.409	6.349 6.383	6.354 6.377
Rat, male	200	6.500	3.079 8.005	6.289 6.820	6 346 6.695	6.441 6.694	6.490 6.510	
Sheep, male, 15 days, female, 1 year	400	4.745	3.079 6.774	4.503 4.972	4.588 4.869	4.665 4.785	4.725 4.764	4.744 4.746
Goat, 1 male, 1 female	400	3.567	2.617 4.080	3.394 4.764	3.401 3.710	3.467 3.693	3.535 3.638	3.546 3.587

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* From an article on Blood Stains by M. C. White, M. D, in *Wood's Handbook of Medicine.*

In this table the measurement of 3,000 corpuscles from man are given, 200 having been taken from each of fifteen different persons. The measurements are given, maximum and minimum, by tens, by twenties, by fifties, by hundreds and by two hundreds. Six hundred from pigs were measured ; 200 from a pig three weeks old, 200 from one of two months, and 200 from a pig three months old.

As the corpuscles of the pig have a larger average than those of the ox, horse, sheep or goat, we make our comparisons between the blood of man and the blood of these three young pigs.

	Mikrons.		Mikrons.
Man, smallest ten	7.658	Largest ten	8.298
Pig, " "	5.418	" "	6.520
Man, smallest twenty	7.662	Largest twenty	8.191
Pig, " "	5.757	" "	6.466
Man, smallest fifty	7.768	Largest fifty	8.079
Pig, " "	5.880	" "	6.240
Man, smallest hundred . .	7.852	Largest hundred	8.046
Pig, " " . . .	6.028	" "	6.169

Smallest ten from man . . . . 7,658 mikrons.
Largest ten from the pig . . . . . . 6,520 "

Difference . . . . . . 1,128 mikrons.
This equals 0.000045 of an inch,—$\frac{1}{22222}$ inch.

Smallest twenty from man . . . . . 7.662 mikrons.
Largest twenty from the pig . . . . . 6,466 "

Difference . . . . . . 1,196 mikrons.
This equals 0.000047 of an inch,—$\frac{1}{21276}$ inch.

Smallest fifty from man . . . . . . 7,768 mikrons.
Largest fifty from the pig . . . . . . 6,246 "

Difference . . . . . . 1,522 mikrons.
This equals 0.000060 of an inch,—$\frac{1}{16666}$ inch.

Smallest hundred from man . . . . 7,852 mikrons.
Largest hundred from the pig . . . . 6,169 "

Difference . . . . . . 1,683 mikrons.
This equals 0.000066 of an inch,—$\frac{1}{15151}$ inch.

We thus see that where only ten corpuscles are measured from man, taking the smallest average of ten consecutively measured, this average for an adult man is one-sixth larger than the largest average of ten consecutively measured from a young pig only three weeks old; while the smallest average of one hundred from man taken consecutively is between one-fifth and one-fourth larger than the largest one hundred taken from the pig.

TABLE SHOWING DISTRIBUTION OF VARIOUS SIZES OF BLOOD-CORPUSCLES MEASURED IN PARTS OF AN INCH. (BY J. B. TREADWELL, M. D.*)

Fractions of an inch	Man.	Dog.	Pig.	Ox.	Sheep.	Goat.
1-2700	2	....	....	....	....	....
1-2800	6	....	....	....	....	....
1-2900	14	....	....	....	....	....
1-3000	32	....	....	....	....	....
1-3100	33	....	....	....	....	....
1-3200	46	6	....	....	....	....
1-3300	37	17	....	....	....	....
1-3400	14	23	2	....	....	....
1-3500	9	24	2	....	....	....
1-3600	4	58	4	....	....	....
1-3700	1	23	17	....	....	....
1-3800	2	12	21	1	....	....
1-3900	....	10	9	3	....	....
1-4000	....	9	31	1	....	....
1-4100	....	12	34	22	....	....
1-4200	....	3	15	16	....	....
1-4300	....	1	7	7	....	....
1-4400	....	2	11	10	....	....
1-4500	....	....	9	17	....	....
1-4600	....	....	8	15	2	....
1-4700	....	....	18	51	15	....
1-4800	....	....	4	15	8	....
1-4900	....	....	4	1	6	....
1-5000	....	....	1	9	19	....
1-5100	....	....	2	8	11	....
1-5200	....	....	0	3	20	....
1-5300	....	....	0	5	17	....
1-5400	....	....	0	3	30	....
1-5500	....	....	1	13	47	....
1-5600	....	....	....	....	11	....
1-5700	....	....	....	....	3	....
1-5800	....	....	....	....	6	3
1-5900	....	....	....	....	1	0
1-6000	....	....	....	....	0	2
1-6100	....	....	....	....	0	2
1-6200	....	....	....	....	0	4
1-6300	....	....	....	....	2	5
1-6400	....	....	....	....	1	30
1-6500	....	....	....	....	0	0
1-6600	....	....	....	....	1	45
1-6700	....	....	....	....	....	20
1-6800	....	....	....	....	....	29
1-6900	....	....	....	....	....	0
1-7000	....	....	....	....	....	15
1-7100	....	....	....	....	....	17
1-7200	....	....	....	....	....	0
1-7300	....	....	....	....	....	15
1-7400	....	....	....	....	....	0
1-7500	....	....	....	....	....	4
1-7600	....	....	....	....	....	4
1-7700	....	....	....	....	....	0
1-7800	....	....	....	....	....	1
1-7900	....	....	....	....	....	0
1-8000	....	....	....	....	....	4
No. of corpuscles..	200	200	200	200	200	200
Maximum........	1-2727	1-3203	1-3473	1-3837	1-4647	1-5892
Minimum........	1-3870	1-4400	1-5500	1-5500	1-6600	1-8048
Mean	1-3197	1-3657	1-4227	1-4654	1-6204	1-6839

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* The number of corpuscles include all found between the fraction opposite to which they are placed and the next succeeding fraction of an inch.

Professor Ewell says—*Medico-Legal Journal*, Vol. X., page 201—that "fasting diminishes both the size and number of the red blood corpuscles. This is also true of various drugs." This agrees with my case of a child six months old, starved to death, given in the preceding table.

A stain from human blood in such a case might possibly be mistaken for that of a dog or a pig. Such a condition might tend to acquit a guilty person, but never to convict of murder an innocent man.

Professor Ewell says: "Many diseases alter the size of the red blood corpuscles," and he gives the result of careful measurements which he has made in a number of diseases. I take great pleasure in acknowledging the excellent work done in this line by Professor Ewell, and, for the present discussion, I have compiled from Professor Ewell's reports the following table:

SOURCE OF BLOOD	No. of corpuscles.	Mean in Mikrons.	Max.	Min.	By 100's Max.	By 100's Min.
Robust Man	650	8.03	9.98	5 03	8.28	7.95
Boy, 36 hours old	200	8.86	11.39	5.70	9.06	8.65
Adult Man	100	7.85	9 32	6.73		
Purpura Hemorrhagica . . .	200	8.26	10.87	3.45	8 28	8.25
Two cases Pseudo Leucocythemia	400	8.04	11.04	6.56	8 55	8.42
Tuberculosis Anemic . .	100	8.35	10.70	5 35		
Plumbism	100	8.65	10.10	5.18		
Gastritis?	100	8 32	10.18	6 22		
Two cases Syphilis	200	8.11	9.32	3.97	8.11	8 11
Erysipelas	100	7.83	9.15	6.90		
Pernicious Anemia	100	7.69	9 93	6.04		
Menstrual blood	100	7.71	8.80	5.76		
	2,350	8.14	11.39	3.45	9 06	7.95

If we take $\frac{1}{3200}$ of an inch, or 7.937 mikrons as the generally accepted average diameter of human blood corpuscles, and compare it with the average obtained by Professor Ewell from blood in diseases, we find his largest average is in plumbism or lead poisoning and is 8.65 mikrons, $\frac{10}{113}$ or a little over one-twelfth part larger than the normal average.

Now, if we take the young pig, which, excepting the dog, is the domestic animal having the largest corpuscles, and to the normal average of the pig, 6.10 mikrons, add $\frac{10}{113}$ its diameter, 0.55 mikrons, we shall obtain for the blood of a diseased pig an average diameter of 6.65, which is smaller by 1.287 mikrons than the average human blood corpuscle.

This possible enlargement by disease is only one-third the difference between the blood corpuscle of man and that of the pig.

Certainly no microscopist of ordinary skill, provided with modern instruments, rated to measure $\frac{1}{1000000}$ of an inch, like the ordinary filar micrometer, with powers of 1,000 or 1,500 diameter; or even the glass eye-piece micrometer, rated to $\frac{1}{100000}$ or even $\frac{1}{50000}$ of an inch, would be in any danger of mistaking blood of even a young pig (whose corpuscles had been enlarged by disease as much as that of the man suffering by lead poisoning) for human blood."

Professor Ewell further objects that "drying the blood corpuscles in a clot multiplies the difficulty of identification," and says: "It has never been proven that dry corpuscles can be restored to their normal proportions," and continuing says: "In view of the foregoing it is impossible in the present state of science to say of a given specimen of blood, fresh or dry, more than that it is (or is not) the blood of a mammal."—*Medico-Legal Journal*, Vol. X., p. 201.

In answer to this objection, I again refer to the table of measurements given above, which I have quoted in part from my article on Blood Stains in *Wood's Handbook*, showing measurements of 3,000 corpuscles of fresh human blood, including males and females of all ages, from the infant at birth to the man of seventy, contrasted with 1,000 corpuscles restored from stains of human blood. The measurements are in mikrons.

Number of Individuals.	Number of corpuscles.	Average.	Max. Min.	By 10's.	By 20's.	By 50's.	By 100's.	By 200's.
Fifteen persons, as stated	3,000	7.938	4.233 10.160	7.658 8.298	7.662 8.191	7.768 8.079	7.852 8.046	7.913 7.983
Blood stains—human	1,000	7.910	5.570 9.687	7.700 8.184	7.723 8.010			
Three young pigs	600	6.101	3.849 8.391	5.418 6.520	5.757 6.466	5.880 6.246	6.028 6.169	6.069 6.144

Here we see that the average of 1,000 corpuscles restored and measured from stains of human blood is 7.910 mikrons, all probably being stains from the blood of adults ; while the average from fifteen persons (three being infants) is 7.938 mikrons, the maximum and minimum, where infants are included, in fresh blood being a little more widely separated than in the restored stains from adults. So also the range, when taken by tens or twenties, is a little less for restored blood than for fresh blood, for the same reason. No closer similarity of results could have been expected had all the measurements been taken from fresh blood, one set including infants and the other taken from adults alone. The fact that there is this difference given above goes to show the great accuracy and perfect restoration of dried blood corpuscles to their normal dimensions.

As a further confirmation of the possibility of restoring dried blood stains to a condition in which their dimensions can be properly compared with fresh blood corpuscles, we copy, by permission, the following table from Professor Wormley's Micro-Chemistry of Poisons :

EXAMINATION OF OLD BLOOD STAINS.

Animal.	Age of Stain.	Remarks.	Average.	Fresh Blood.
(1) Human .	2 months old,	Stain unknown	$\frac{1}{3358}$ in.	$\frac{1}{3250}$ in.
(2) " .	2½ " "	Stain	$\frac{1}{3336}$ in.	$\frac{1}{3250}$ in.
(3) " .	3 " "	"	$\frac{1}{3334}$ in.	$\frac{1}{3250}$ in.
(4) " .	19 " "	Clot	$\frac{1}{3390}$ in.	$\frac{1}{3250}$ in.
(5) Elephant,	13 " "	"	$\frac{1}{2849}$ in.	$\frac{1}{2738}$ in.
(6) Dog . . .	4 " "	Trace of stain unknown,	$\frac{1}{3536}$ in.	$\frac{1}{3561}$ in.
(7) Rabbit . .	18 " "	Clot	$\frac{1}{3683}$ in.	$\frac{1}{3653}$ in.
(8) Ox . . .	16 " "	Stain	$\frac{1}{4544}$ in.	$\frac{1}{4319}$ in.
(9) " . . .	32 " "	Stain unknown	$\frac{1}{4498}$ in.	$\frac{1}{4319}$ in.
(10) " . . .	4½ years old .	Clot	$\frac{1}{4535}$ in.	$\frac{1}{4319}$ in.
(11) Buffalo .	18 months old .	"	$\frac{1}{4513}$ in.	$\frac{1}{4351}$ in.
(12) Goat . . .	17 " " .	Stain	$\frac{1}{5897}$ in.	$\frac{1}{6189}$ in.
(13) Ibex . . .	18 " "	Clot	$\frac{1}{6578}$ in.	$\frac{1}{6445}$ in.

In the case of the human blood No. 1, two months old, the deposit was in the form of a thin stain on muslin, and its nature, other than that it was mammalian blood, was unknown at the time of examination. The corpuscles were readily found, and two series of thirty corpuscles were measured. In the human blood two and a half months old, fifty corpuscles, ranging from $\frac{1}{3125}$ to $\frac{1}{3448}$ of an inch were measured.

The blood stain of the dog, No. 6, was prepared by Dr. Frankenberg, and consisted of a single stain so minute as to be barely visible to the naked eye; its nature at the time of the examination was unknown. In the ox blood four and a half years old, the corpuscles were readily obtained, and two closely concordant series of measurements were made.

The table of Professor Formad, Collective Results of Some of the Series of Measurements of Red Blood Corpuscles in Blood Stains, in his article on Mammalian blood (*Journal of Medicine and Surgery*, July, 1888, copied in the *Medico-Legal Journal*, Vol. X., p. 157), proves still further the successful recovery and measurement of red corpuscles from dried blood stains.

These tables show that blood corpuscles can be, and have been, recovered and measured and found to correspond with the average of fresh blood of the same animal from which the stain was taken as closely as the corpuscles of any two animals of the same species correspond when fresh.

The only remaining possibility of mistaking stains from blood of a pig, ox, horse, sheep or goat for human blood, when fifty or one hundred corpuscles have been measured and found to average 7.9 mikrons, or even 7.0 mikrons, is to suppose that the blood corpuscles have become larger than fresh blood, or that the expert has *wickedly* and *purposely* measured only the largest corpuscles and has not done honest work.

Professor Ewell says that "by selecting the corpuscles it would be possible for a dishonest observer to make the average much larger or smaller than the above given (in his table) without the possibility of detection—a fact the bearing of which upon the value of expert testimony upon this subject is so obvious as to need no comment." We have never claimed, and shall not now claim, that it is any more difficult for a witness to swear falsely in regard to blood stains than in regard to any other subject. But it would be quite possible on cross examination to ask the expert whether in measuring the corpuscles obtained from a stain he had measured all the well-defined corpuscles in the field of the microscope, or whether he had selected the large corpuscles and rejected others which were smaller.

In the case of State of Connecticut vs. Herbert H. Hayden, Superior Court Special, October term, 1879, Dr. J. J. Woodward, U. S. A., gave testimony for the defense in regard to examination of blood stains.* He stated that in 1875 he had published in the *American Journal of Medical Science* the measurements of thirteen sets of human blood corpuscles, about fifty in each set. The average diameter of the whole series was 0.000295 inch. The largest set of fifty corpuscles measured 0.000304 inch, and the smallest set 0.000295 inch, but that he left out some of the larger corpuscles because they were not perfectly circular, and that the result would give an average rather too small for the general average of human blood.

That he also measured nine sets of about fifty in a set from the blood of a dog; the average of the nine sets from the dog was 0.000290 inch. Some of the averages of fifty from the dog were larger than some of the averages from men, though the average from all dogs would be smaller than the average from all men. These were measured with an eye-piece micrometer ruled on glass.

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* **Report of Court Stenographer printed by Black & Bryant, Boston, Mass.**

In 1876 he published in the Proceedings of the American Medical Association measurements of twenty-two sets of corpuscles from men and thirteen sets from one dog. The average of all the sets from men, then published, was 0.000323 inch, which is larger than Gulliver's measurement of $\frac{1}{3200}$ inch by eleven millionths of an inch, but some of his averages of 150 corpuscles from a dog, published at that time, were also larger than some of his averages of 150 in a set from men.

All the measurements above referred to, published in 1876, were measured on photographic negatives.

Dr. Woodward also stated in the same case :

> Within the last two or three weeks I have made a still further series of measurements of man and dog. I used for the purpose a cobweb micrometer, and the lens which of all other lenses in my acquaintance defines the best—namely, one of the Zeiss lenses ; Zeiss of Jena.
>
> With that lens and with a cobweb micrometer I made a series of measurements of forty corpuscles of human blood—it was from one of the assistants in the museum. I brought the corpuscle into the center of the field and I measured it with the cobweb micrometer, that is by turning the screw I set the cobweb on the extreme limit of the corpuscle so that the cobweb line just touched the edge on the outside, and then the readings of the turns of the screw gave the number of divisions.
>
> I got an average of those forty corpuscles of 327 millionths of an inch—This was fifteen millionths of an inch larger than $\frac{1}{3200}$ of an inch. Now, in these 40 corpuscles, the biggest individual was 366 millionths of an inch.
>
> Then I pricked my own finger and took a drop of my own blood and I measured fifty corpuscles, and there I got the average size to be 324 millionths of an inch, that you see is three millionths of an inch smaller than I just got on another set.
>
> Then in another sample of human blood I got the figure 316 millionths of an inch on the measurements of twenty corpuscles. This last figure would differ only four millionths of an inch from Gulliver's $\frac{1}{3200}$ of an inch.
>
> I measured, on the 14th of December of the present month, fifty corpuscles of the blood of a dog ; it was a Newfoundland crossed with setter ; a pup four weeks old. I measured fifty corpuscles, and the average was 326 millionths of an inch.
>
> Q. Differing, I see, only one millionth of an inch from the first forty corpuscles of human blood ?
>
> A. Yes, and larger than my second fifty, larger than any of that set of human measurements, except the first, and larger than any of the photographic

measurements I have published of dogs' blood except one. Well, then I measured another dog's blood on the 12th of December, a Scotch terrier, forty corpuscles, and I got an average of 320 millionths of an inch.

Q. That, I see, is larger than the last for human blood ?

A. It is larger than the last for human blood, and larger than the $\frac{1}{3200}$ of Gulliver.

Q. It is larger by eight millionths than Gulliver's average ?

A. Yes, sir ; then also on the 14th of December I measured another dog's blood, a Gordon setter, full grown, and his blood was smaller than either of the young dogs I have spoken of, the average of twenty-nine corpuscles was 300 millionths of an inch.

Q. Excuse me for asking you how much larger that is than your figures published in 1875, of human blood ?

A. It is five millionths of an inch larger.

Q. Then, if I understand it, you measured several other dogs at this time?

A. Not at this time, those were all I measured at this time, and I desire to put myself on record as distinctly denying that those measurements of the dog's blood would represent what you would be likely habitually to get if without picking out young dogs, and without selecting a spot to measure appearing to have unusually large corpuscles you were to measure dog's blood. You would then habitually get smaller figures than I have given here. The averages of the corpuscles of dogs would habitually be smaller than I have given here, but I have purposely selected for fixed measurements young dogs, for I knew they had bigger corpuscles, and, in the second place, in taking an old dog, I purposely selected a place (on the slide) where, to my trained eye, I saw there was a group of big corpuscles ; that is the place on the thing I was measuring. My reason for doing that is to show that if you pick up a half dozen corpuscles at chance, you may chance on these big things. But I have nowhere stated, on the contrary I would like to read my express statement from my printed utterance, that the general average for the dog, for a great number of measurements, will be less than for a great number of men.

Q. You have stated that your object in selecting these dogs, and these large corpuscles of these dogs, was to show how it might innocently happen that in the measurements of a given number of corpuscles, say twenty, or thirty, or forty, or fifty, as you have here, you might get this large average ?

A. Yes, and you would get it if you stumbled upon such a group.

In relation to the dark border of the corpuscle, Dr. Woodward said :

When you look at a blood corpuscle, for instance, in a microscope of high power, there appears to be a certain thickness at the edge ; there is a certain dark shadow at its edge, and that has a certain degree of thickness. Now, should you measure all the shadow as blood corpuscle, or none as blood corpuscle, or shall you measure one-half of that shadow as blood corpuscle ? There is always more or less uncertainty about that. I myself have always thought, when the objective of the highest definition was used; when we had exquisite defining power, and when, in consequence, the shadow which accompanies the corpuscle is more nearly round, you may safely bisect it with the cobweb, setting one on one shadow and one on the other, so as to take in a half shadow on each side as part of the corpuscle, but if you have taken in the whole you would get slightly larger measurements.

On cross-examination by Mr. Waller, in regard to the shadow or dark border of the corpuscle, Dr. Woodward said:

A. My opinion is that about one-half of that line is shadow.

Q. I ask you now, in your measurement, how much of that doubtful quantity that we call shadow, do you include in your measurement of the corpuscle?

A. I always include half of the surrounding dark area.

In treating blood stains with solvents of fibrin, to liberate the corpuscles for measurement, it has been found in many cases that the corpuscles were smaller than in fresh blood, unless maceration was long continued, old stains requiring several weeks before the corpuscles were in a condition to be measured. When a bi-concave blood corpuscle is placed in water, the coloring matter (hemaglobin) is dissolved out, the corpuscle swells up, thickens at the edges, becomes transparent and spherical. In this condition the diameter of the corpuscle becomes less than normal. It thus happens in examining blood stains that all corpuscles which have lost their color or have become spherical are by some experts rejected and not measured. Some corpuscles in fresh blood have much more coloring matter than others, and these corpuscles retain their color and form (as we think) much longer than paler corpuscles. We are not aware that any fluid used, or likely to be used, for softening blood stains, will cause the corpuscles to become larger than normal. This point, I admit, requires further investigation.

If the corpuscles obtained from a stain do not recover their normal dimensions, it is almost absolutely certain that their average measurement will be less than normal and *never* greater than normal. Thus, in the language of Professor Wormley, we may confidently say: "*Thus then, whilst the blood of man might, on account of contraction in diameter of* *the blood corpuscles, be confounded with that of some animal having smaller corpuscles, the reverse could never occur.*"

Professor E. S. Wood in *Witthaus & Becker's Medical Jurisprudence*, Vol. II., p. 42 : "There is no reagent that we know of at the present time, and no influence outside of the living body, which tends to increase the diameter of the red corpuscles."

From this discussion we claim that it has been proved beyond any reasonable question :

1. That in favorable cases blood stains can be so treated that reliable measurements and credible diagnosis of their origin can be given, as shown in the tables given and in others which might be referred to.

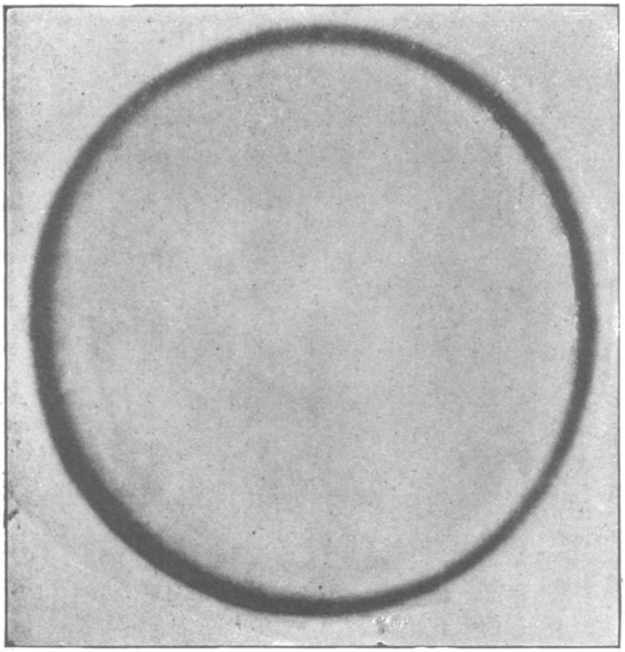
2. That if error occurs on account of imperfect restoration of the form and diameter of the corpuscles obtained from a stain proved [by (*a*) the Guaiacum test, (*b*) the spectroscope, (*c*) by the production of hemin crystals] to be blood, the error, if any, will be to make human blood appear like that of one of the inferior animals, and never to mistake the blood of the ox, pig, horse, sheep or goat for human blood.

3. In general, when a stain has been proved to be blood by the above tests, it may be decided certainly whether it is or is not mammalian blood. So, also, a stain from the blood of the ox, pig, horse, sheep and goat may be distinguished from human blood : thus confirming the claim of an accused person in many cases that his clothes are *not* stained with human blood. This negative testimony is certainly quite as important in many cases as testimony inculpating a prisoner.

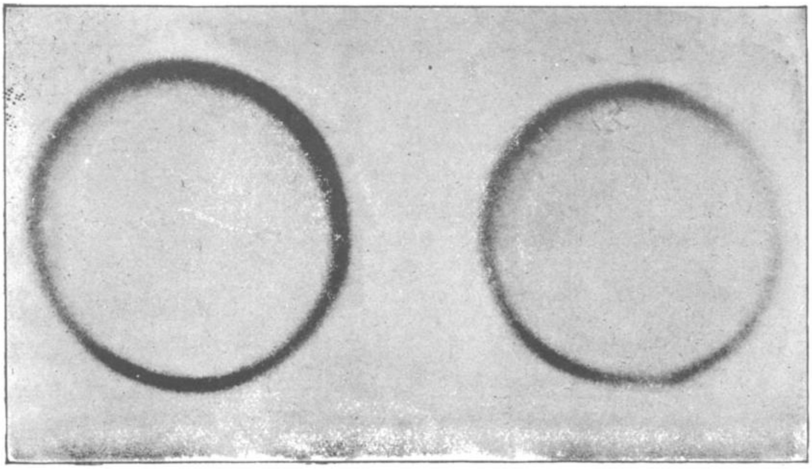
Lastly, the expert can say, when the average of a suitable number of corpuscles from a blood stain corresponds with the average of fresh human corpuscles, that the stain is certainly not from the blood of the ox, pig, sheep or goat ; and in other cases he can say, with great certainty, that a given stain is not human blood.

Such testimony, by a skilled microscopist, is of untold importance in saving the lives of the innocent, and often in overthrowing the plea of those who are guilty. Such testimony is quite as reliable and important to the welfare of society as that of the chemist who testifies to the presence or absence of poison that might have some resemblance to the many recently discovered ptomaines.

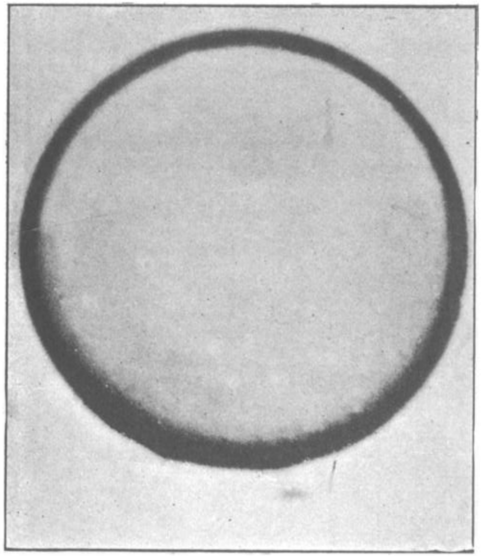
NOTE.—All the photoengravings in the following pages which are represented as magnified × 2560 are from negatives on wet plates by J. B. Treadwell, M. D., of Boston. Those magnified × 10850 diameters are enlargements made by the writer from the negatives × 2560 of J. B. Treadwell. Plate × 840 and all marked × 640 are from photographs made by the author, and show very clearly the appearance seen in ordinary good microscopes of moderate power at the present day. M. C. W.



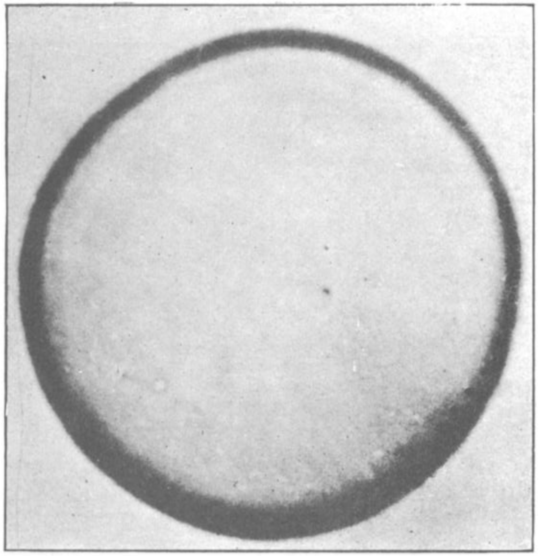
Human Blood, Red Corpuscle—X 10850.



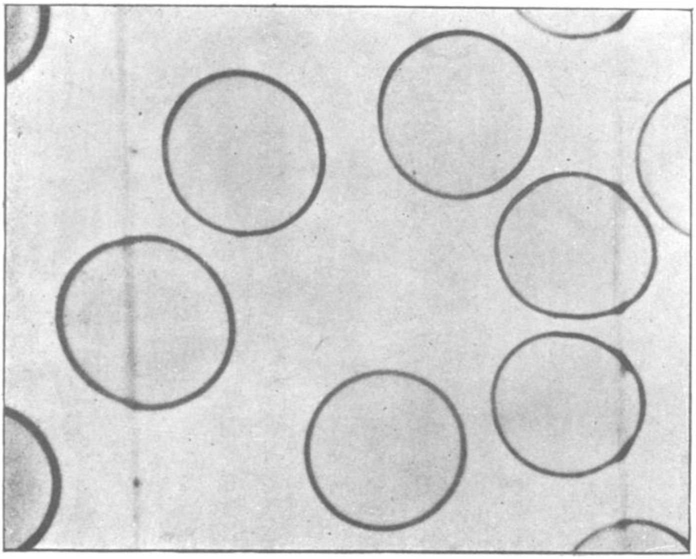
Red Blood Corpuscles of Goat—X 10850.



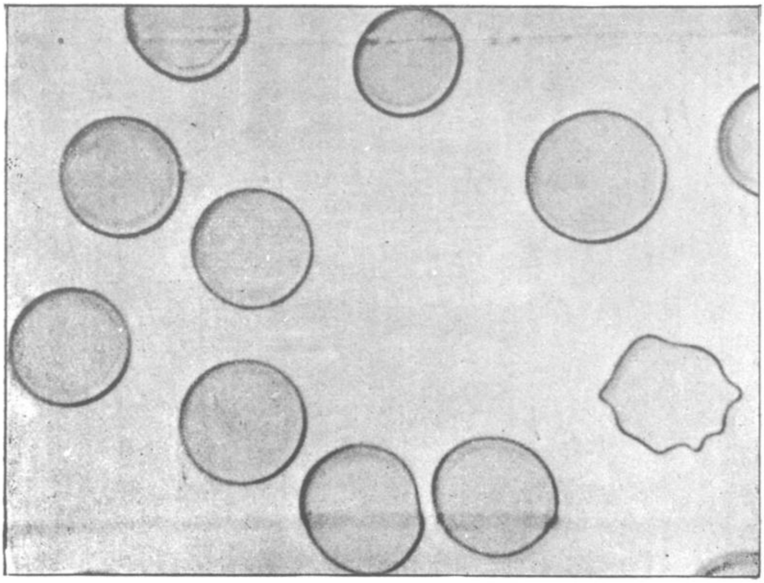
Red Blood Corpuscle, Pig—X 10850.
Small size.



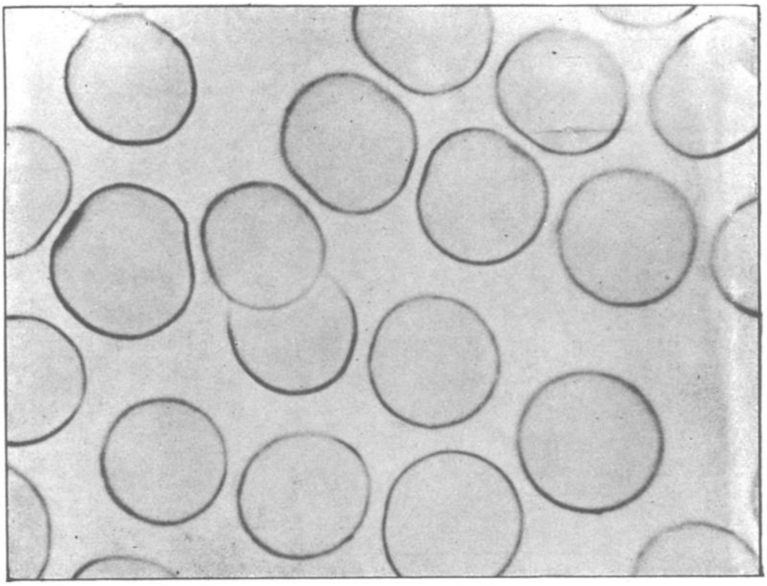
Red Blood Corpuscle, Pig, Medium—X 10850.



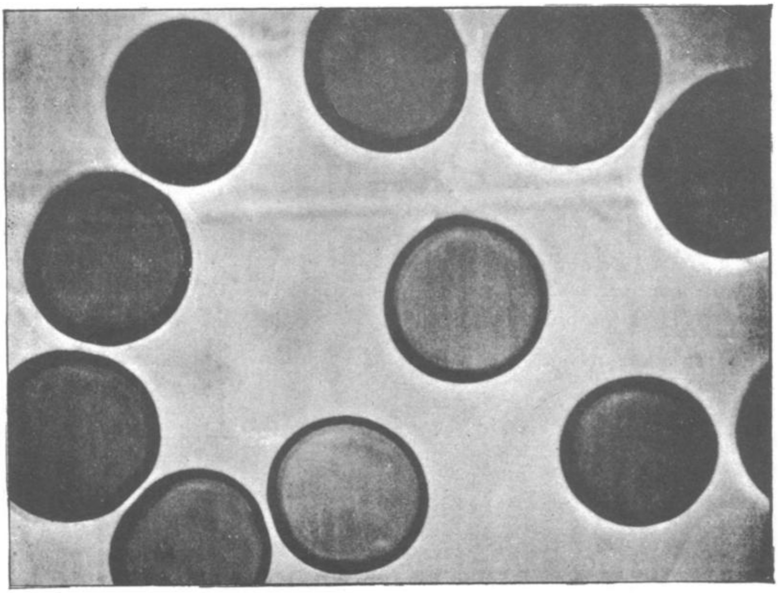
Human Red Blood Corpuscles—X 2560, with Micrometer Lines $\frac{1}{1000}$ inch.



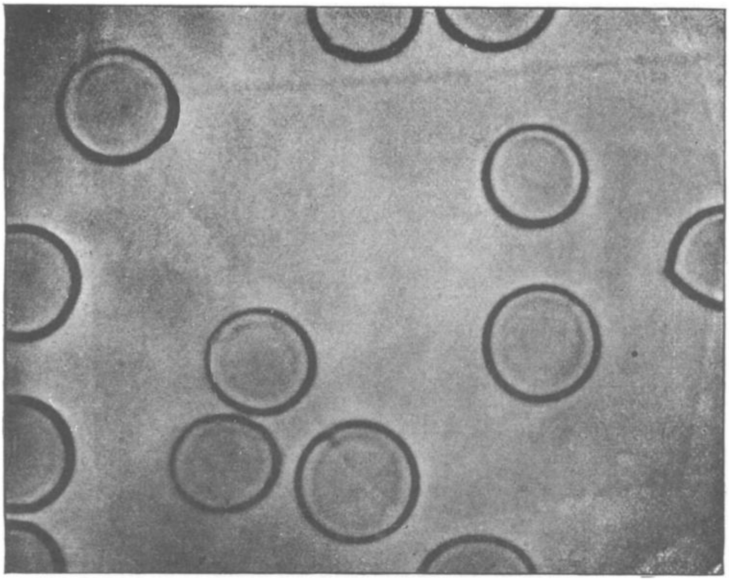
Red Blood Corpuscles of Pig—X 2560, with Micrometer Lines $\frac{1}{1000}$ inch



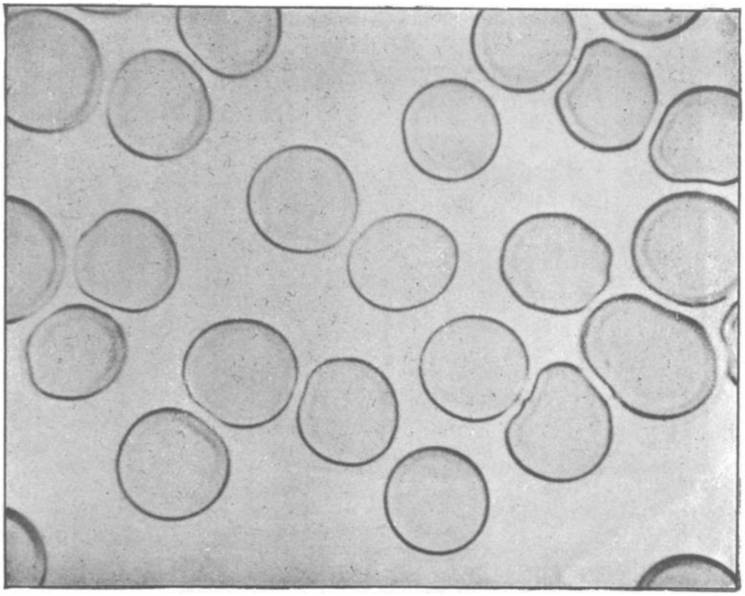
Red Blood Corpuscles of Mongrel Dog—X 2560.



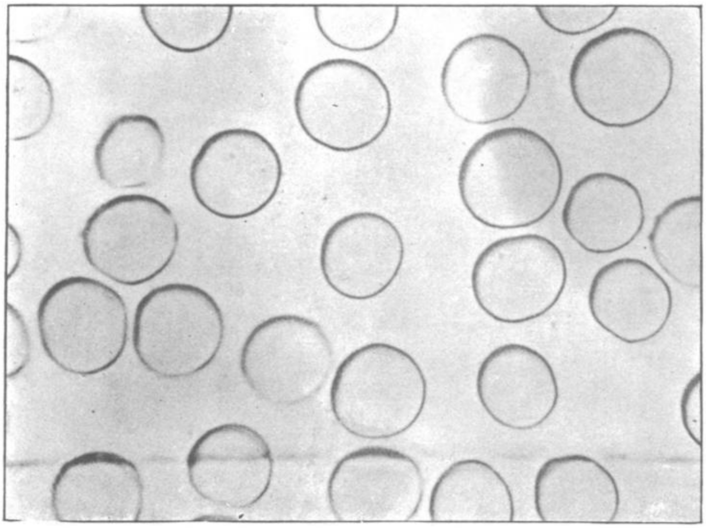
Red Blood Corpuscles of Man—X 2560. As seen when out of focus.



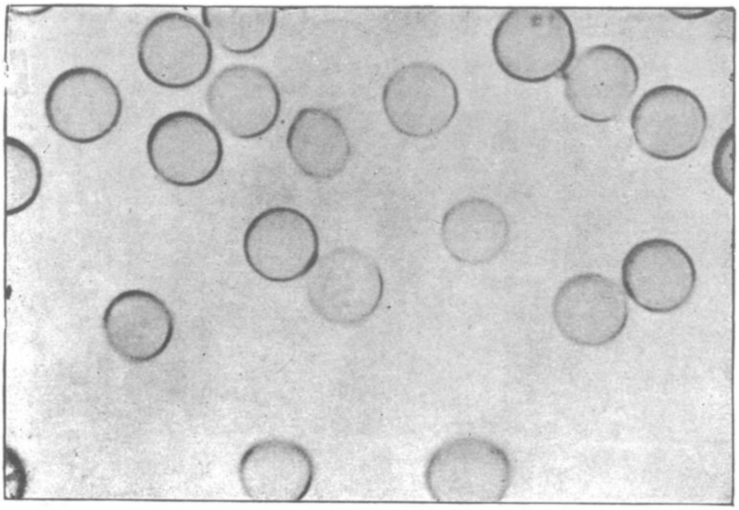
Red Blood Corpuscles of Ox—X 2560.



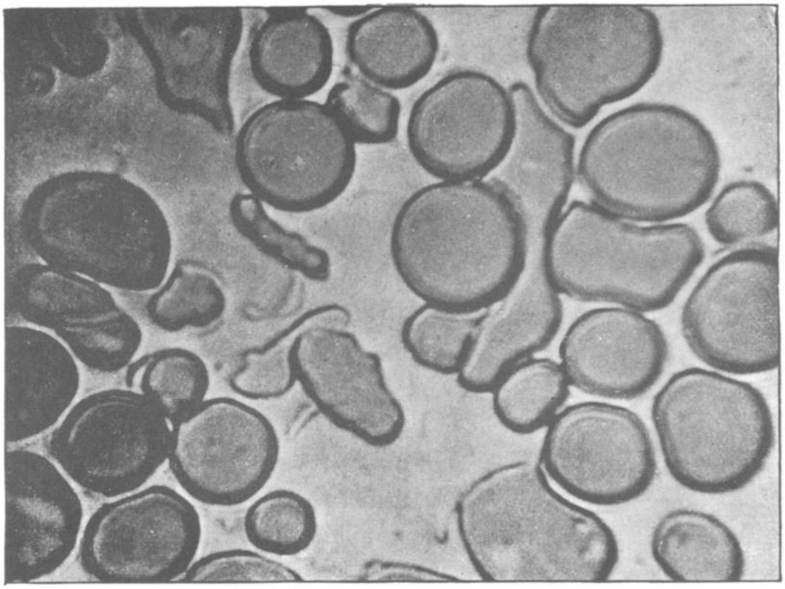
Red Blood Corpuscles of Horse—X 2560.



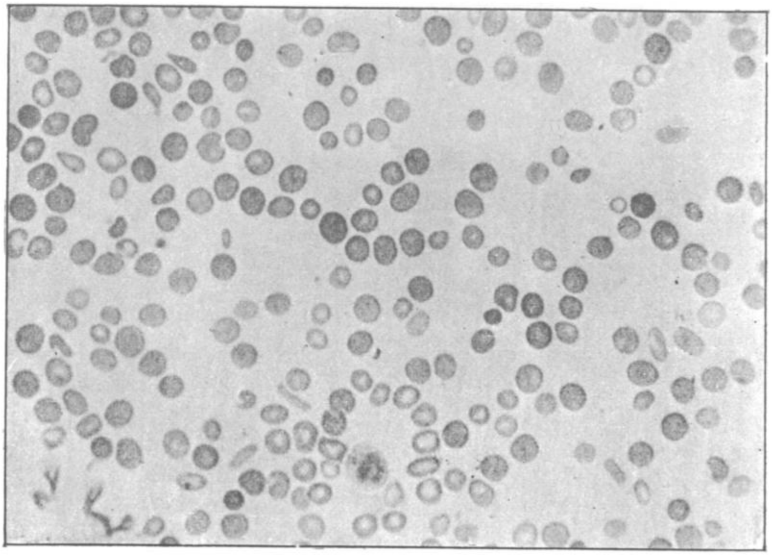
Red Blood Corpuscles of Sheep—X 2560.



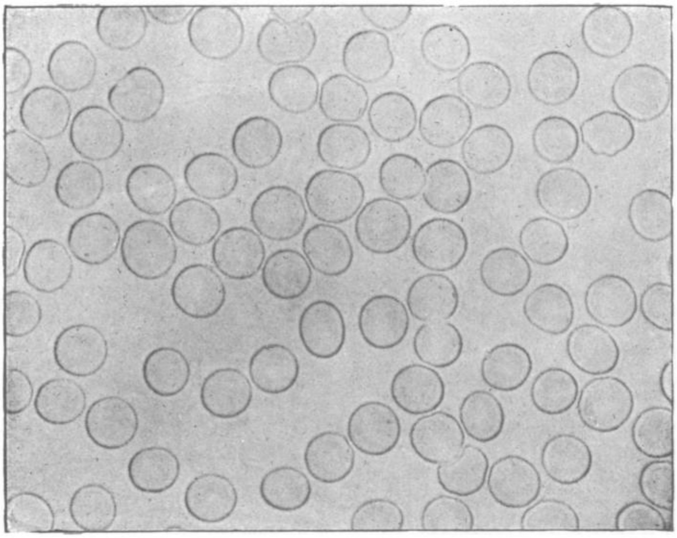
Red Blood Corpuscles of Goat—X 2560.



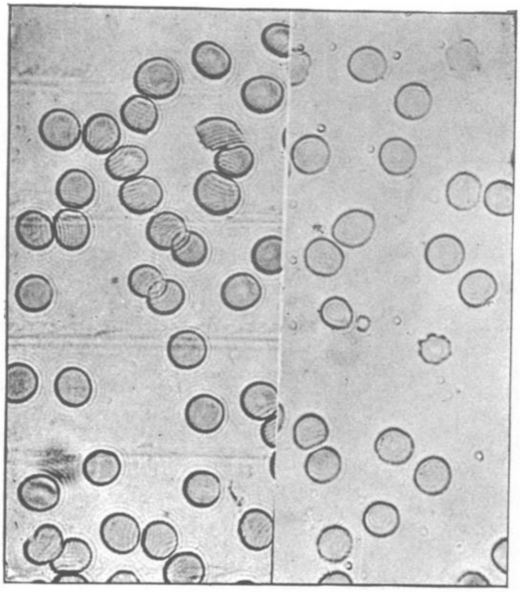
Human Blood Corpuscles (Pernicious Anemia)—X 2560.



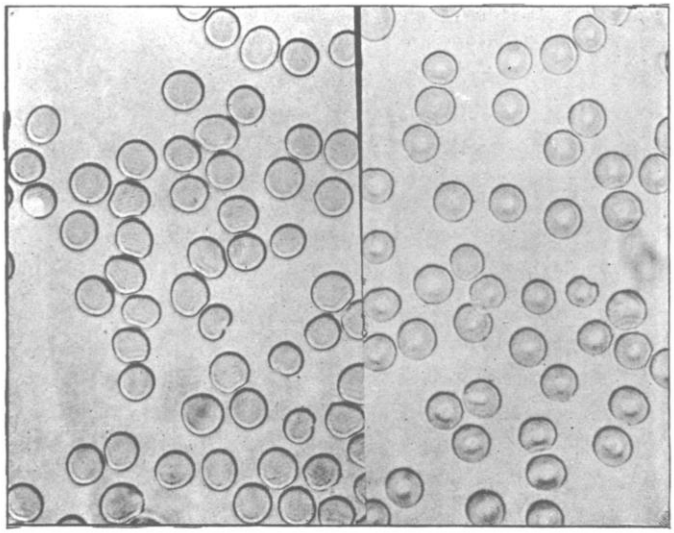
Red Blood Corpuscles, Man (Anemia)—X 600. Very small and generally small size. Photo. by W. N. Sherman, M. D., of Merced, Cal.



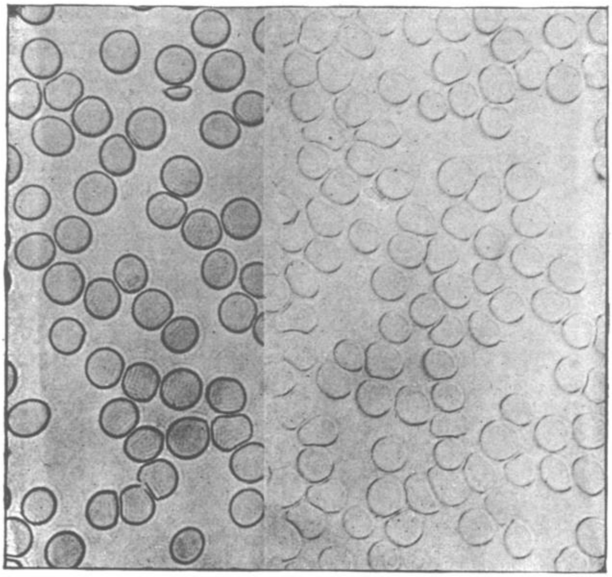
Red Blood Corpuscles (Human)—X 840.



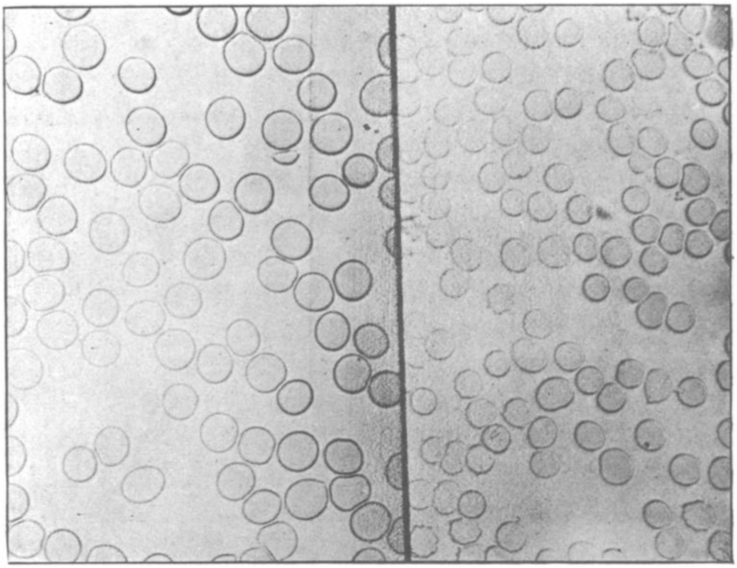
Blood of Man—X 640. Blood of Guinea Pig—X 640.



Blood of Man—X 640. Blood of Pug Dog—X 640.

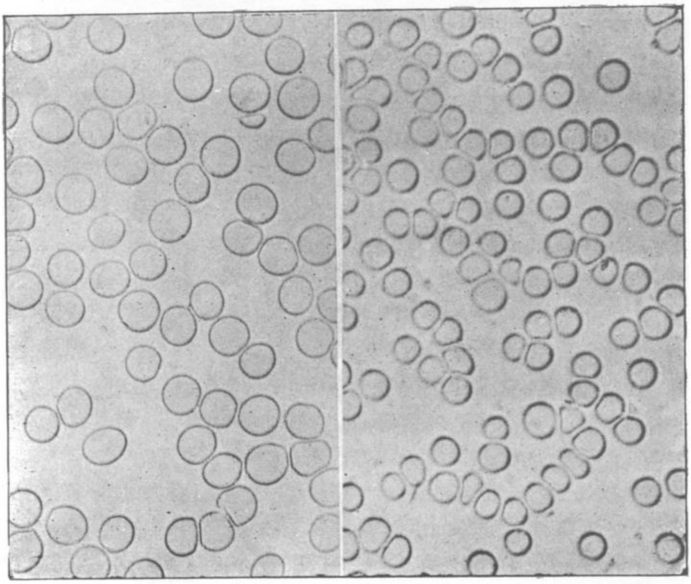


Human Blood -X 640. Blood of Bull Dog--X 640.



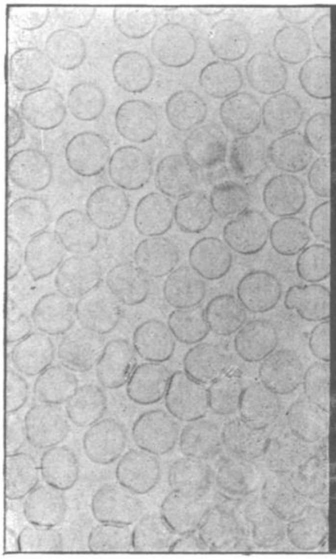
Human Blood—X 640.

Blood of Young Calf—X 640.

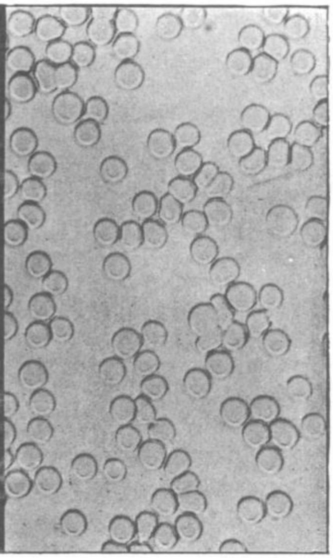


Blood of Man—X 640.

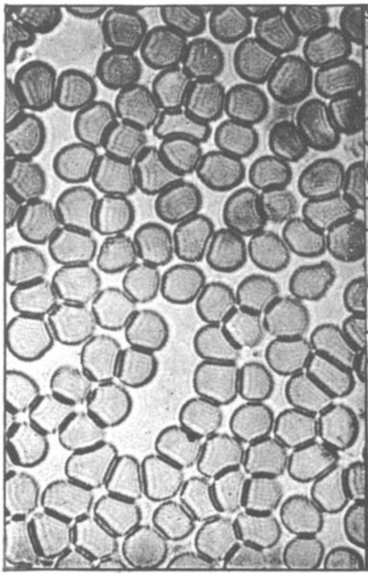
Blood of Ox—X 640.



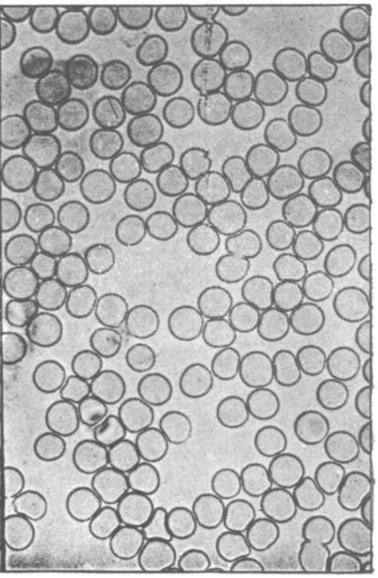
Human Blood—X 640.



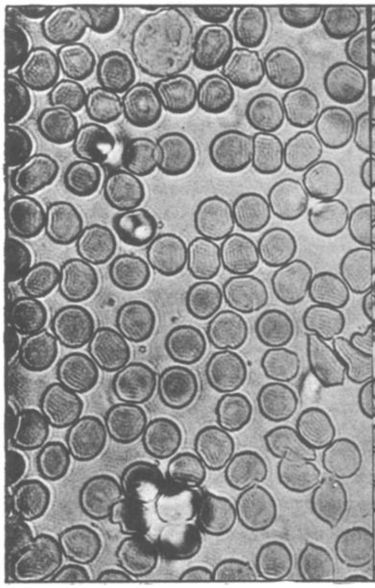
Blood of Cat—X 640.



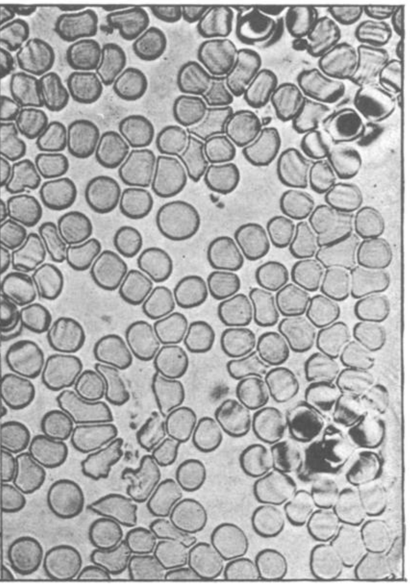
Human Blood—X 640.



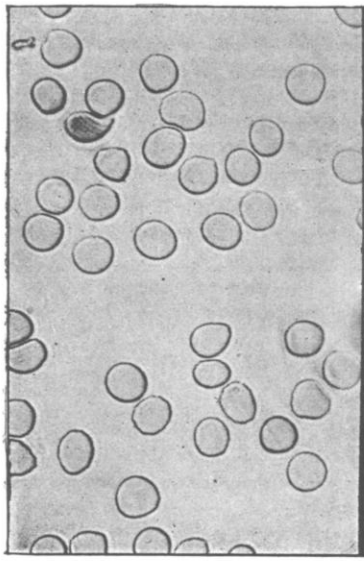
Blood of Ass— X 640.



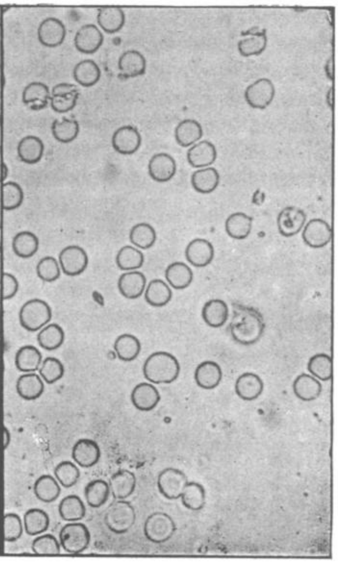
Human Blood—X 640.



Blood of Pig—X 640.



Blood of Man—X 640.



Blood of Sheep—X 640.